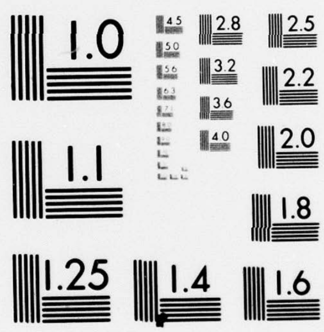
AD-A057 690 NAVAL RESEARCH LAB WASHINGTON D C F/G 20/7
A QUALITATIVE DESCRIPTION OF THE MODIFIED TRITON ELECTRON BEAM --ETC(U)
JUN 78 J D SETHIAN
UNCLASSIFIED NRL-MR-3785 SBIE-AD-E000 182 NL

| OF |

AD
A057690

END
DATE
FILMED
9-78
DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(12)

7/3

adu000182

SC

NRL Memorandum Report 3785

A Qualitative Description of the Modified TRITON Electron Beam Accelerator

J. D. SETHIAN

Experimental Plasma Physics Branch
Plasma Physics Division

LEVEL II

June 1978

NAVAL RESEARCH LABORATORY
Washington, D.C.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
NRL Memorandum Report 3785 ✓

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER
9

4. TITLE (and Subtitle)
6 A QUALITATIVE DESCRIPTION OF THE MODIFIED TRITON ELECTRON BEAM ACCELERATOR.

5. TYPE OF REPORT & PERIOD COVERED
Interim report on a continuing NRL problem.

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
10 J. D. Sethian

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Naval Research Laboratory
Washington, D.C. 20375

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
NRL Problem H02-28B

11. CONTROLLING OFFICE NAME AND ADDRESS
Office of Naval Research
Arlington, Virginia 22217

12. REPORT DATE
11 June 1978

13. NUMBER OF PAGES
14

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
12 14p.

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

14 NRL-MR-3785

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18 SBIE 19 AD-E000 182

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Blumlein
Relativistic electron beam generator
Diode

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The TRITON accelerator was designed to produce an intense relativistic electron beam for plasma physics research. The present program called for a more energetic electron beam than currently produced. A description of the original accelerator, and the subsequent modifications to increase the beam energy, risetime, reproducibility and reliability are presented.

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

251 950

A QUALITATIVE DESCRIPTION OF THE MODIFIED TRITON ELECTRON BEAM ACCELERATOR

INTRODUCTION

The Triton accelerator[1] was designed to produce an intense relativistic electron beam for plasma physics research. Currently, this research concerns the investigation of the reversed field magnetic confinement geometry generated with plasma currents induced by a rotating relativistic electron beam.[2] While previous experiments have demonstrated this concept[3], the decay of the configuration, although consistent with classical processes, was, because of the low plasma electron temperatures, comparable to the free streaming end loss time. Thus, in order to achieve the higher electron temperatures required to verify axial containment, it was deemed necessary to increase the energy of the relativistic electron beam. It was also desirable to decrease the beam rise time and fall time, in order to increase the strength of the field-reversing current layer, and to decrease the shot-to-shot variation in the beam characteristics. These objectives were achieved by modifying the pulse forming network and prepulse switch of the existing TRITON accelerator. This report contains a description of these modifications, and the results achieved with them.

Note: Manuscript submitted May 9, 1978.

TRITON Mk I

The original TRITON accelerator (hereinafter referred to as TRITON Mk I) consisted of an 8 Ohm Blumlein charged by a 1 MV Marx generator and discharged into a planar field emission diode. Elimination of any prepulse was achieved by a self-break switch located in the cathode shank.

The 12 stage Marx (.5 μf per stage) was erected by means of twelve 5/8 inch gap spark switches housed in a single switch column. The first two switches were triggered, and the remaining ten closed by over-voltage. Ultraviolet irradiation of the unfired switches, by those already closed, resulted in an acceptably low jitter in the erection time of the Marx. By adjusting the pressure of the 10% SF_6–90% N_2 gas mixture in the switch column, the Marx could operate between 55 and 90 kV.

The pulse forming network was a water dielectric Blumlein consisting of three coaxial cylindrical conductors, as shown in Fig. 1. The intermediate conductor was charged with respect to the outer and inner conductors (the two being electrically connected through the prepulse inductor), thereby transforming the Blumlein into two coaxial transmission lines linked in parallel. A triggered switch connected the two coaxial lines in series, and thereby discharged their stored energy into the diode. The triggered switches were a necessity, in order to synchronize injection of the relativistic electron beam with the firing of a Q-switched ruby laser for Thomson scattering diagnostics, and thus permit measurements of the plasma density and temperature during the beam pulse. However, access for the switch trigger cables required that the switches

be placed between the intermediate and outer conductors. As a negative pulse is required at the cathode, this, in turn, required the intermediate conductor to be positively charged. Because the electric fields necessary to produce breakdown in water for a positively charged surface are about half that necessary for a negatively charged surface, the intermediate conductor had to have a relatively large radius of curvature.

Optimal breakdown characteristics were found to occur when the thickness of the intermediate conductor was about twice the gap spacing of the inner coaxial line. Such a thick intermediate conductor was fabricated of stressed thin wall aluminum sheet welded to four aluminum ribs, similar to the monocoque construction practice used in Formular I Grand Prix racing cars in the early 1960's.

The diode consisted of a simple carbon cathode-aluminized mylar foil anode arrangement. The prepulse was eliminated with a self break switch consisting of two brass plates isolated by a lucite tube, and located in the cathode shank.

While the TRITON Mk I performed well initially, several flaws in its performance surfaced in time: i) It was found that the four triggered switches, which required their own Marx generator and pulse line, needed servicing after 75 shots. This proved to be a serious limitation, as the entire system was capable of running at 6-10 shots per day. ii) If the diode failed to conduct properly, breakdown between the conductors of the Blumlein took place. As this breakdown was in water, a considerable force was exerted on the intermediate conductor. This force buckled the aluminum skin inward and produced large ragged edge holes

that severly reduced the electric fields necessary to produce water breakdown. Consequently, the Blumlein could not be charged to its full potential, and the energy in the electron beam was considerably less than that indicated by the original design parameters. iii) The self break prepulse switch behaved erratically, leading to shot-to-shot variations in the beam characteristics. Moreover, the lucite tube in the switch needed to be replaced after only 25-30 shots.

TRITON Mk II

In view of these shortcomings, coupled with the desire to increase the energy in the relativistic electron beam, it was decided to modify TRITON Mk I. As the Marx was capable of storing 15 kJ (at 80 kV), yet the resulting REB contained only 1.4 kJ, it was decided that the primary effort would be directed towards increasing the efficiency of the Blumlein and the reliability and reproducibility of the prepulse switch. The final design is shown in Fig. 2. In order to alleviate the constraints imposed by a positively charged intermediate conductor, and thus allow for a more rugged construction, it was decided to discharge the Blumlein by a self-break water switch (details are in Fig. 3) that connects the inner and intermediate conductors. While this design is expected to result in a shot-to-shot jitter in the beam firing of $\pm$ 100 nsec, it was decided to be acceptable in view of the intense x-ray flux that precluded Thomson scattering measurements within 100 nsec after beam injection. For simplicity and cost considerations, the original 72 inch long, 25 inch radius stainless steel tank of TRITON Mk I was used. The intermediate conductor is 217 cm long, giving a one way transit time of 50 nsec,

and a resulting pulse of 100 nsec. (This represents a 40% increase over TRITON Mk I.) The conductor is supported at one end by a lucite diaphragm, and at the other by a single nylon support rod. The center conductor is supported by a lucite diaphragm at one end, and by its own buoyant force at the other. (The buoyancy is achieved by sealing off a sufficient volume of the inner conductor to displace the exact amount of water necessary to render it weightless.) The intermediate conductor is fabricated of a single aluminum tube (with nominal wall thickness 1.3 cm) welded to a standard dished head. The inner conductor is similarily constructed, except the head is fabricated of a solid billet of aluminum in order to withstand the shock of the water switch breakdown. The electrode in the inner conductor is formed from stainless steel and held to the aluminum head by four allen head cap screws. The intermediate conductor electrode is also composed of stainless steel, and is connected to the Marx via a sliding connection. Electrode adjustment is carried out by a bevel gear drive, turned by a removable keyed shaft. The back diaphragm, between the Marx and Blumlein, is fabricated of a 2.5 cm thick piece of polyethylene, in order to absorb the shock breakdown of the water switch. (Hysteresis in the polyethylene has proven to be quite low, thus alleviating the necessity of readjustment of the water switch gap on a periodic basis. In fact, tests to date show no gap adjustment has been necessary over 100 shots.) The adjustable prepulse switch, following a design of Fuleihan and Hammer[4], is composed of two electrodes facing each other, and attached to a pair of parallel diaphragms. The left hand diaphragm in Fig. 2 is made of 5 cm thick lucite, with the electrode connected directly to the center conductor, whereas the right hand dia-

phragm is made of flexible 2.5 cm thick polyethylene, with the electrode attached to the cathode via a telescoping coupling. The gap is adjusted by pumping transformer oil from a resevoir into the space between the diaphragms. As the polyethylene expands, water is forced up the standpipe until it provides a sufficient head to balance the pressure of the oil pump. Adjustment of the switch, then, is a simple matter of throttling the oil pump.

The performance of TRITON Mk II, and a comparison with TRITON Mk I is shown in Fig. 4. In each case the upper trace is the output of a capacitive voltage divider in the diode, and the lower trace is the output from a magnetic probe measuring the current through the cathode shank. The energy in the relativistic electron beam, from $\int I \cdot V \, dt$ and verified with a carbon calorimeter, has been increased from 1.4 kJ to 6.4 kJ. Other shots have shown beam energies in excess of 8 kJ. This increase is manifested in both higher currents and longer pulse lengths. Another improvement has been achieved through the new prepulse switch. By adjusting the gap spacing to approximately 2 mm, the voltage rise time can be reduce to less than 30 nsec. (With the gap completely closed, a sufficient prepulse ($\sim$100 kV) is present to form a plasma in the anode cathode gap and result in a prematurely closed diode.) A multishot foil changer enables the anode foil to be replaced after each shot without breaking the system vacuum. Thus, in normal operation, the generator can be fired with a repetition rate of once every three-to-four minutes. After 10-15 shots, the diode interface must be cleaned and re-oiled to prevent surface flashover. Total turnaround time is less than one hour.

This relatively high repetition rate and short turnaround time should be quite valuable in determining the scaling laws and physics governing the rotating beam-induced reversed field configuration.

Special thanks are due to J.K. Burton, D. Conte and J.D. Shipman, who provided helpful suggestions in the modification design, and to Mr. A.K. Kinkead for his technical assistance.

References

1. J. K. Burton, J. J. Condon, M. D. Jevnager, W. H. Lupton, and T. J. O'Connell, in Proceedings of the Symposium on Engineering Problems of Fusion Research, (IEEE, New York, 1974) p. 613.
2. D. A. Hammer, A. E. Robson, K. A. Gerber and J. D. Sethian, Phys. Lett. 60A, 31 (1977).
3. J. D. Sethian, D. A. Hammer, K. A. Gerber, D. N. Spector, A. E. Robson and G. C. Goldenbaum, Naval Research Laboratory Memorandum Report No. 3648, Washington, D.C. (Nov. 1977).
4. D. A. Hammer and E. L. Fuleihan. Private Communications.

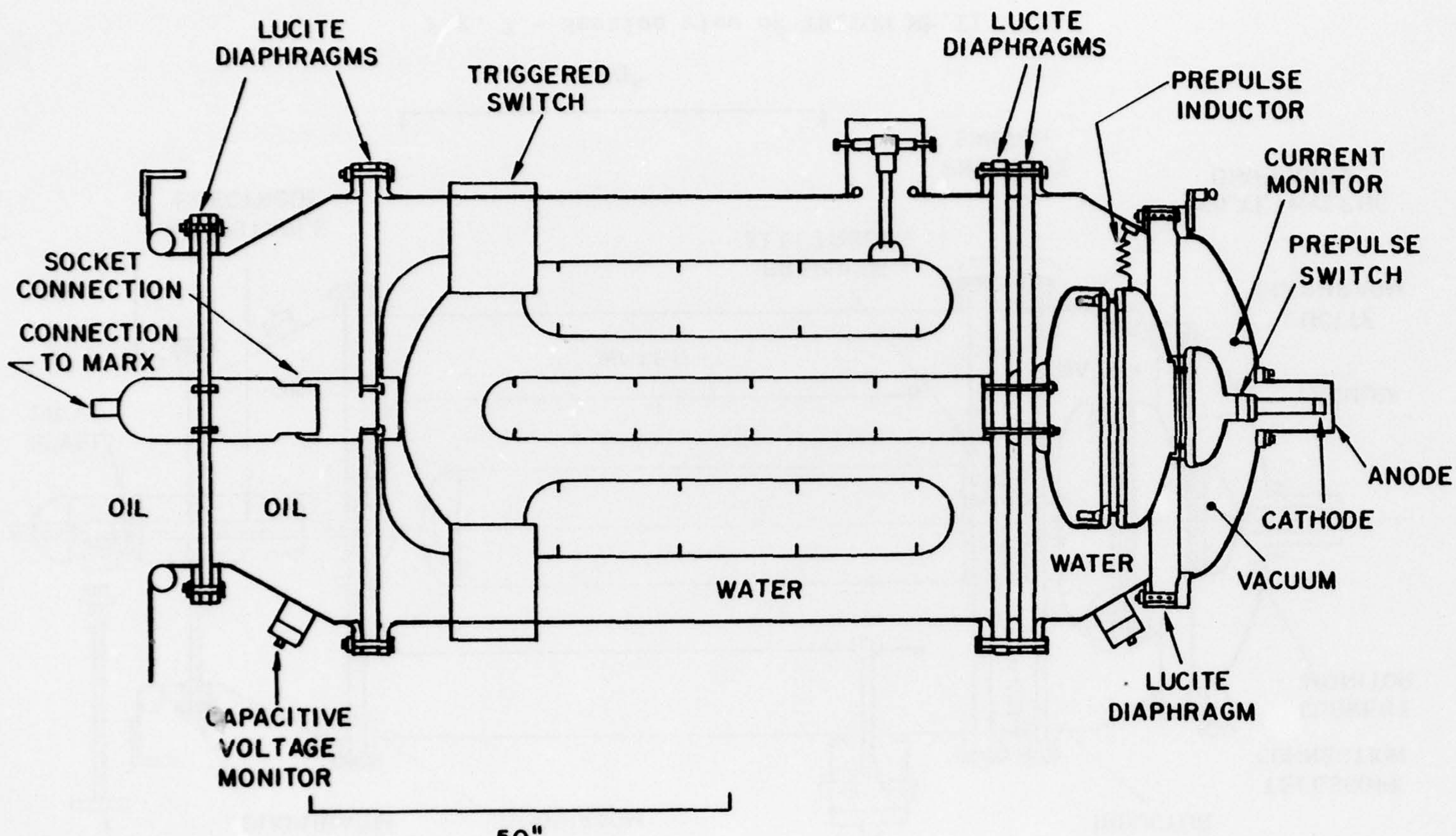


Fig. 1 - Section view of TRITON Mk I.

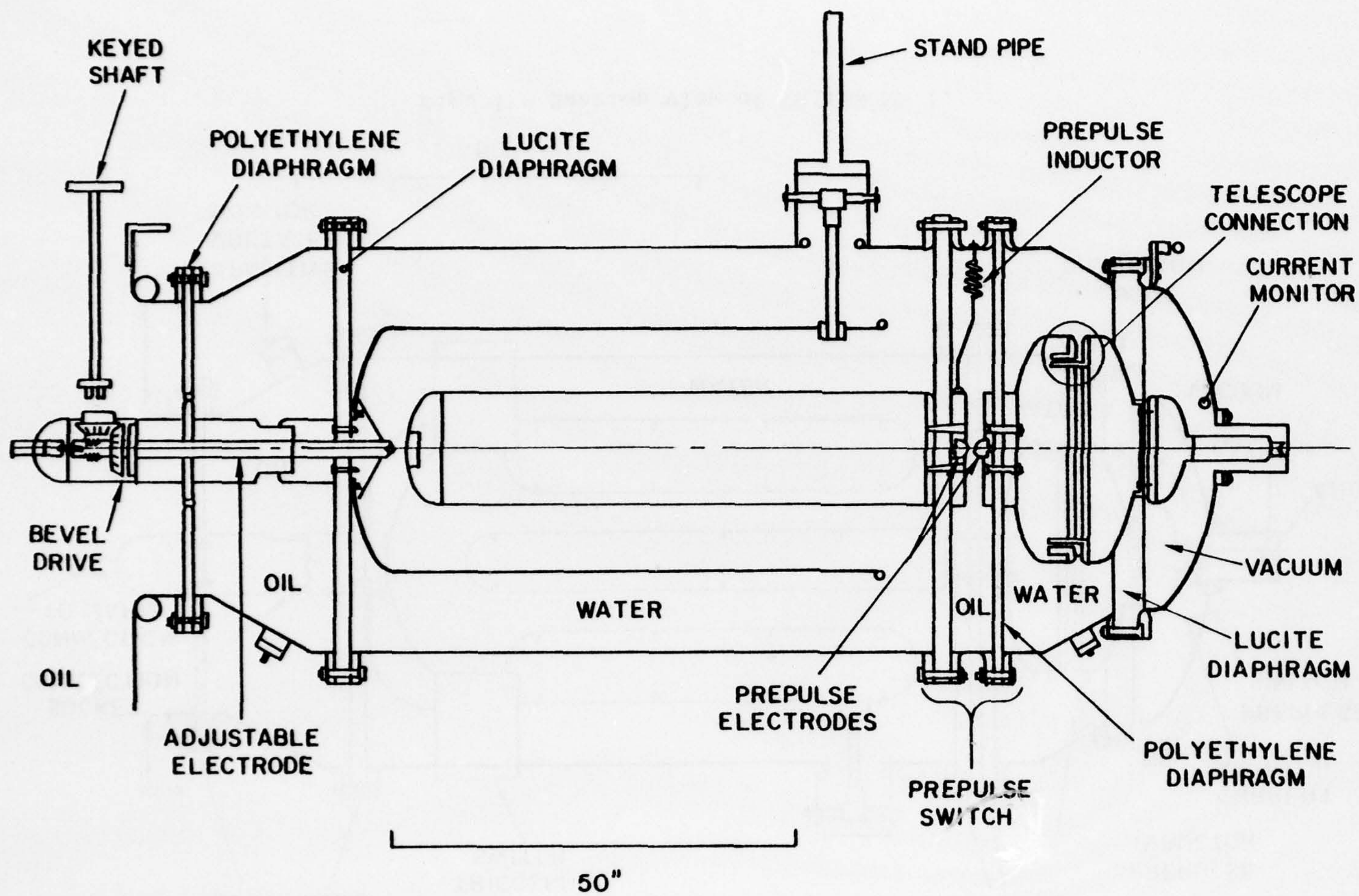


Fig. 2 - Section view of TRITON Mk II

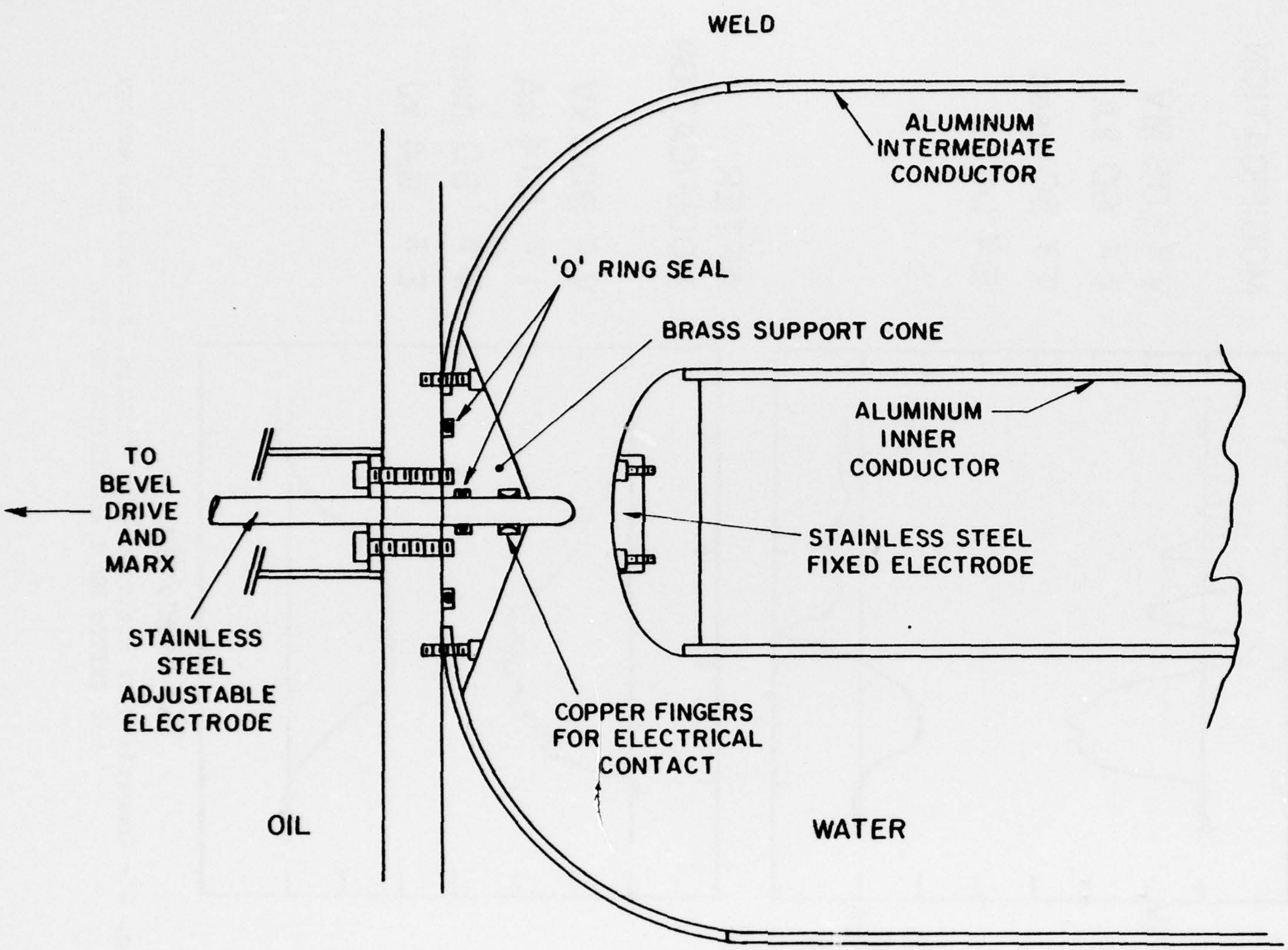


Fig. 3 - Detail of self-break water switch.

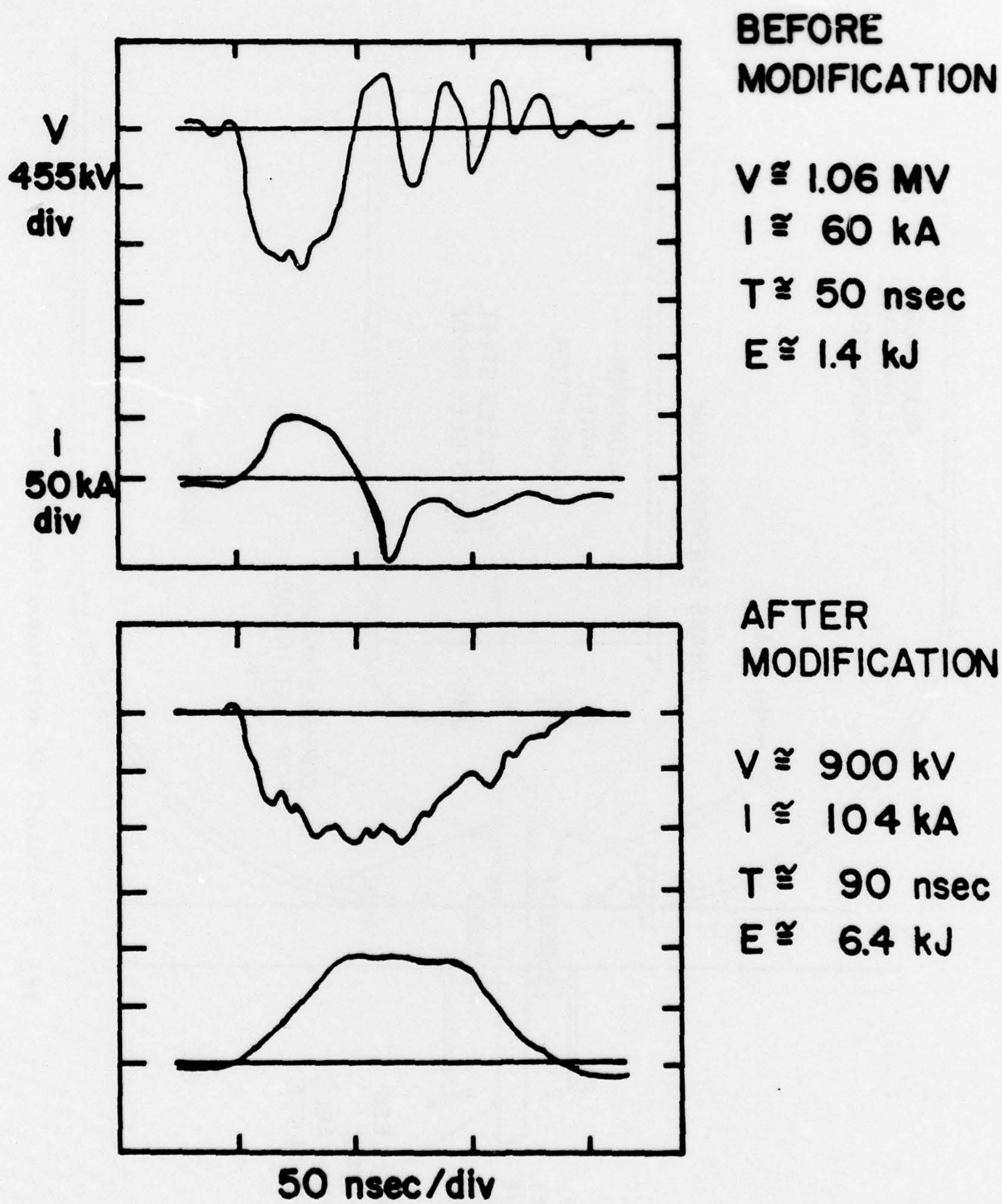


Fig. 4 - Comparison of electron beam voltage, current and energy for TRITON Mk I and TRITON Mk II.